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Summary of Progress on Prior NCST Investigations

June 8-9, 2022
NCST Advisory
Committee Meeting

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NIST
National Institute of
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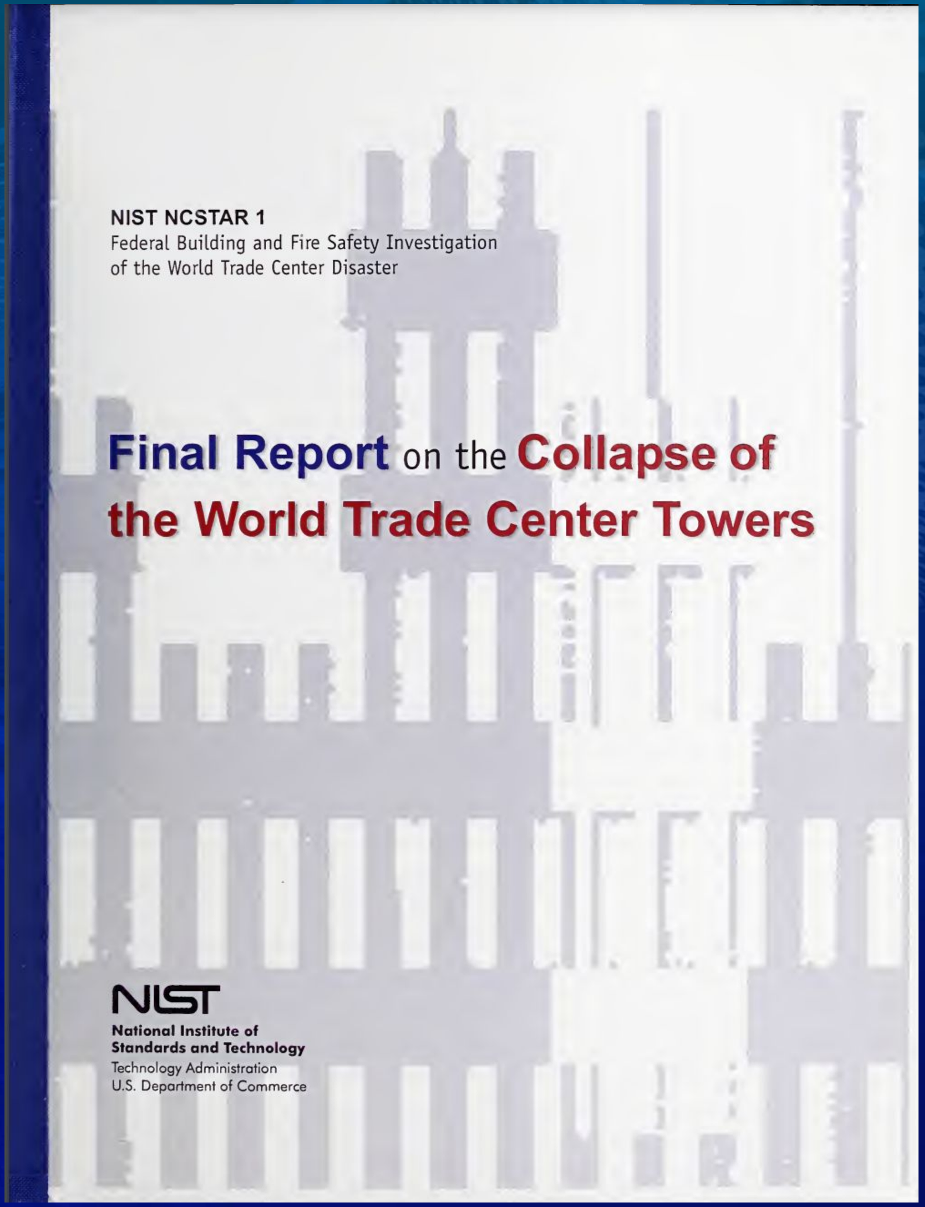
U.S. Department of Commerce

June 8-9, 2022
NCST Advisory
Committee Meeting

World Trade Center Investigation

NOTE – Summaries of the recommendations are included in the following slides for context. The complete recommendations are available in the final report of the NIST Technical Investigation, at https://www.nist.gov/el/final-reports-nist-world-trade-center-disaster-investigation

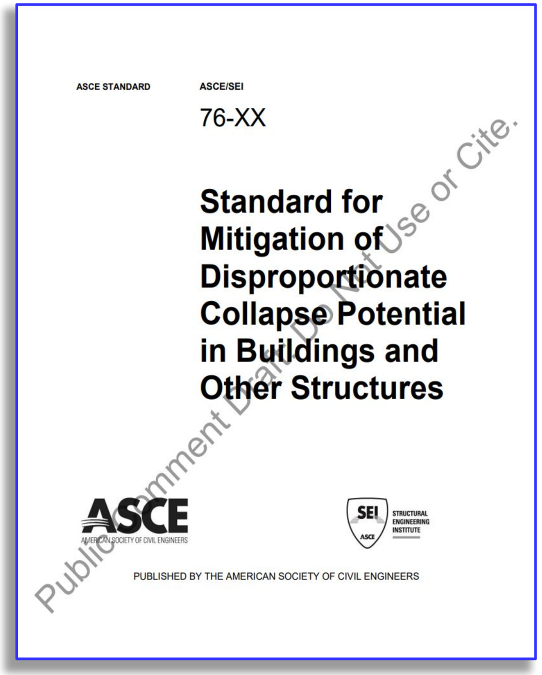

NIST NCSTAR 1
Federal Building and Fire Safety Investigation
of the World Trade Center Disaster

Final Report on the Collapse of the World Trade Center Towers

NIST
National Institute of
Standards and Technology
Technology Administration
U.S. Department of Commerce

Progress on Implementation of WTC Recommendations

Recommendation 1	Progress Update
NIST recommends that progressive collapse be prevented in buildings through the development and nationwide adoption of consensus standards and code provisions, along with the tools and guidelines needed for their use in practice	• In FY2012, based on NIST's proposal, a new ASCE/SEI *Disproportionate Collapse Mitigation Standard Committee* was established. • Draft Standard was completed and released for public comments (April 01 – May 16, 2022).


ASCE STANDARD

ASCE/SEI

76-XX

Standard for Mitigation of Disproportionate Collapse Potential in Buildings and Other Structures

ASCE

AMERICAN SOCIETY OF CIVIL ENGINEERS

SEI STRUCTURAL ENGINEERING INSTITUTE

PUBLISHED BY THE AMERICAN SOCIETY OF CIVIL ENGINEERS

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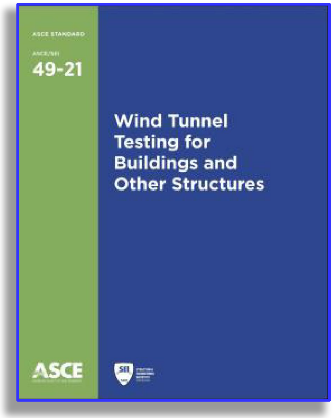
WTC

Progress on Implementation of WTC Recommendations

WTC

Recommendation 2	Progress Update
NIST recommends performance standards be developed for: (1) conducting wind tunnel testing of prototype structures that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings, based on wind tunnel testing data and directional wind speed data.	• Revision of ASCE 49 Wind Tunnel Testing Standards were approved and published as ASCE 49-21 • Revision to wind velocity pressure profiles in ASCE 7-22, to better reflect the state-of knowledge on atmospheric boundary-layer flows



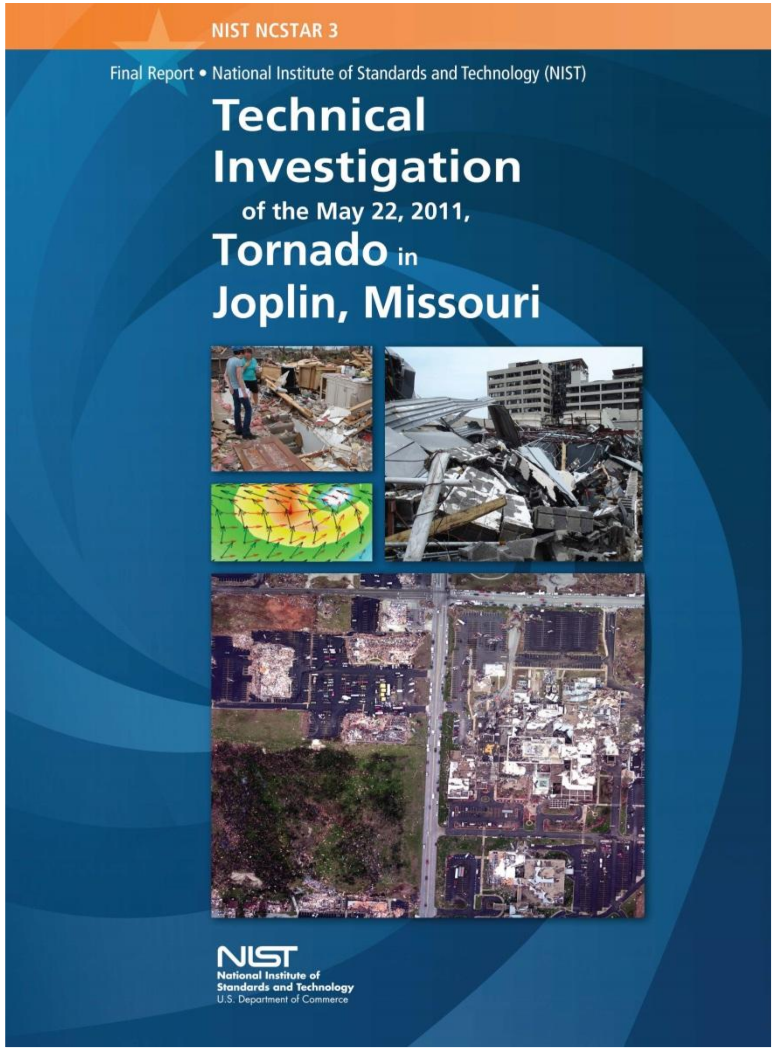
June 8-9, 2022
NCST Advisory
Committee Meeting

Joplin Tornado Investigation

NOTE – Summaries of the recommendations are included in the following slides for context. The complete recommendations are available in the final report of the NIST Technical Investigation of the Joplin Tornado, at https://dx.doi.org/10.6028/NIST.NCSTAR.3

National Institute of Standards and Technology
U.S. Department of Commerce

NIST Joplin Tornado Investigation



http://dx.doi.org/10.6028/NIST.NCSTAR.3

The first tornado study to include storm characteristics, building performance, emergency communication and human behavior together - with assessment of the impact of each on fatalities

- **16 recommendations for improving:**
  - Tornado hazard characterization
  - Design and construction of buildings and shelters in tornado–prone regions
  - Emergency communications that warn of threats from tornadoes
- **Implementation of recommendations began in Spring 2014, immediately following publication of final report**

JOPLIN

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JOPLIN

List of Joplin Recommendations

	R #	RECOMMENDATION SUMMARY
Hazard Characteristics	1	Development and deployment of technology to measure tornado wind fields
	2	Archival of tornado event data
	3	Development of tornado hazard maps
	4	Improvement of EF Scale; means for continued improvement; adoption by NWS
Buildings, Shelters, Designated Safe Areas, and Lifelines	5	Development of performance-based standards for tornado-resistant design
	6	Development of performance-based tornado design methodologies
	7	a) Development of tornado shelter standard for existing buildings; b) Installation of tornado shelters in more buildings in tornado-prone regions
	8	Development of guidelines for public tornado sheltering strategies
	9	Development of guidelines for selection of best available refuge areas
	10	Prohibition of aggregate roof coverings and ballast in tornado-prone regions
	11	Development of requirements for enclosures of egress systems in critical facilities
	12	a) Development of tornado vulnerability assessment guidelines for critical facilities; b) Performance of vulnerability assessments by critical facilities in tornado-prone
Emergency Communication	13	Development of codes, standards, and guidance for emergency communications; Development of joint plan by emergency managers/media/NWS for consistent alerts
	14	Deployment of “push” technologies for transmission of emergency information
	15	Research to identify factors to enhance public perception of personal risk
	16	Develop technology for real-time, spatially-resolved tornado threat information

List of Joplin Recommendations

JOPLIN

	R #	RECOMMENDATION SUMMARY – PROGRESS UPDATES IN THIS BRIEFING
Hazard Characteristics	1	Development and deployment of technology to measure tornado wind fields
	2	Archival of tornado event data
	3	Development of tornado hazard maps
	4	Improvement of EF Scale; means for continued improvement; adoption by NWS
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	10	Prohibition of aggregate roof coverings and ballast in tornado-prone regions
	11	Development of requirements for enclosures of egress systems in critical facilities
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	16	Develop technology for real-time, spatially-resolved tornado threat information

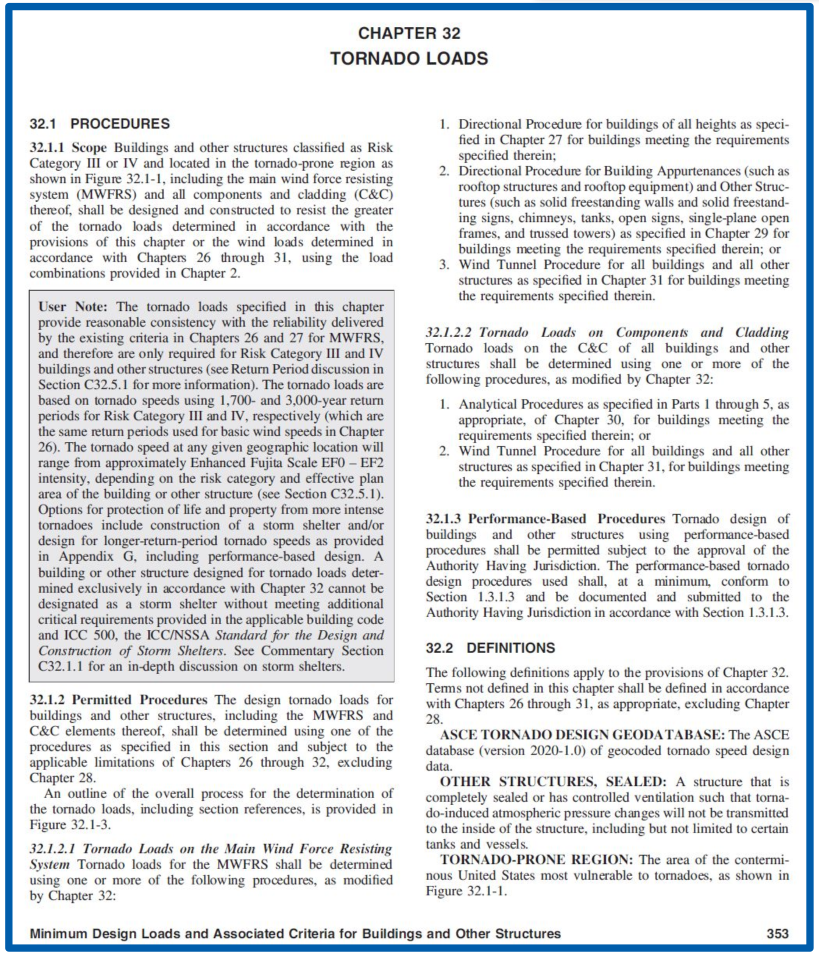
Highlights of Implementation Activities and Successes since Last Meeting (1/2)

JOPLIN

Recommendations 5, 6: Tornado hazard maps and load methodology for tornado resistant design approved as the new Chapter 32 of ASCE 7-22

- Includes performance-based design provisions

ASCE/NIST/FEMA proposal for inclusion of tornado design provisions into the 2024 International Building Code (IBC) passed the IBC Structural Committee at ICC Committee Action Hearings in April (14-0 vote)



CHAPTER 32
TORNADO LOADS

32.1 PROCEDURES

32.1.1 Scope Buildings and other structures classified as Risk Category III or IV and located in the tornado-prone region as shown in Figure 32.1-1, including the main wind force resisting system (MWFRS) and all components and cladding (C&C) thereof, shall be designed and constructed to resist the greater of the tornado loads determined in accordance with the provisions of this chapter or the wind loads determined in accordance with Chapters 26 through 31, using the load combinations provided in Chapter 2.

User Note: The tornado loads specified in this chapter provide reasonable consistency with the reliability delivered by the existing criteria in Chapters 26 and 27 for MWFRS, and therefore are only required for Risk Category III and IV buildings and other structures (see Return Period discussion in Section C32.5.1 for more information). The tornado loads are based on tornado speeds using 1,700- and 3,000-year return periods for Risk Category III and IV, respectively (which are the same return periods used for basic wind speeds in Chapter 26). The tornado speed at any given geographic location will range from approximately Enhanced Fujita Scale EF0 – EF2 intensity, depending on the risk category and effective plan area of the building or other structure (see Section C32.5.1). Options for protection of life and property from more intense tornadoes include construction of a storm shelter and/or design for longer-return-period tornado speeds as provided in Appendix G, including performance-based design. A building or other structure designed for tornado loads determined exclusively in accordance with Chapter 32 cannot be designated as a storm shelter without meeting additional critical requirements provided in the applicable building code and ICC 500, the ICC/NSSA *Standard for the Design and Construction of Storm Shelters*. See Commentary Section C32.1.1 for an in-depth discussion on storm shelters.

32.1.2 Permitted Procedures The design tornado loads for buildings and other structures, including the MWFRS and C&C elements thereof, shall be determined using one of the procedures as specified in this section and subject to the applicable limitations of Chapters 26 through 32, excluding Chapter 28.

An outline of the overall process for the determination of the tornado loads, including section references, is provided in Figure 32.1-3.

32.1.2.1 Tornado Loads on the Main Wind Force Resisting System Tornado loads for the MWFRS shall be determined using one or more of the following procedures, as modified by Chapter 32:

1. Directional Procedure for buildings of all heights as specified in Chapter 27 for buildings meeting the requirements specified therein;
2. Directional Procedure for Building Appurtenances (such as rooftop structures and rooftop equipment) and Other Structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, single-plane open frames, and trussed towers) as specified in Chapter 29 for buildings meeting the requirements specified therein; or
3. Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31 for buildings meeting the requirements specified therein.

32.1.2.2 Tornado Loads on Components and Cladding Tornado loads on the C&C of all buildings and other structures shall be determined using one or more of the following procedures, as modified by Chapter 32:

1. Analytical Procedures as specified in Parts 1 through 5, as appropriate, of Chapter 30, for buildings meeting the requirements specified therein; or
2. Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31, for buildings meeting the requirements specified therein.

32.1.3 Performance-Based Procedures Tornado design of buildings and other structures using performance-based procedures shall be permitted subject to the approval of the Authority Having Jurisdiction. The performance-based tornado design procedures used shall, at a minimum, conform to Section 1.3.1.3 and be documented and submitted to the Authority Having Jurisdiction in accordance with Section 1.3.1.3.

32.2 DEFINITIONS

The following definitions apply to the provisions of Chapter 32. Terms not defined in this chapter shall be defined in accordance with Chapters 26 through 31, as appropriate, excluding Chapter 28.

ASCE TORNADO DESIGN GEODATABASE: The ASCE database (version 2020-1.0) of geocoded tornado speed design data.

OTHER STRUCTURES, SEALED: A structure that is completely sealed or has controlled ventilation such that tornado-induced atmospheric pressure changes will not be transmitted to the inside of the structure, including but not limited to certain tanks and vessels.

TORNADO-PRONE REGION: The area of the conterminous United States most vulnerable to tornadoes, as shown in Figure 32.1-1.

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 353

Highlights of Implementation Activities and Successes since Last Meeting (2/2)

JOPLIN

Recommendation 4:
Tornado field data collection to support improvements to EF Scale and damage modeling

Dec. 10-11, 2021 Quad-State Tornado Outbreak

- Historic Event
  - 71 Tornadoes
- Deadliest December Outbreak
  - 90 direct, 3 indirect fatalities
- 2 key, high impact EF-4 tornadoes:
  - 81 and 167 miles long

Source: NWS

Top 5 most significant natural disaster events in 2021, with $4B insured loss

Source: Aon, Catastrophe Insight (2022)

Dawson Springs
DoD 3
5/15 Windows
Broken

Mayfield
DoD 3
1/10 Windows
Broken

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Tornado Hazard Characteristics

Performance of Buildings, Shelters, Designated Safe Areas, and Lifelines

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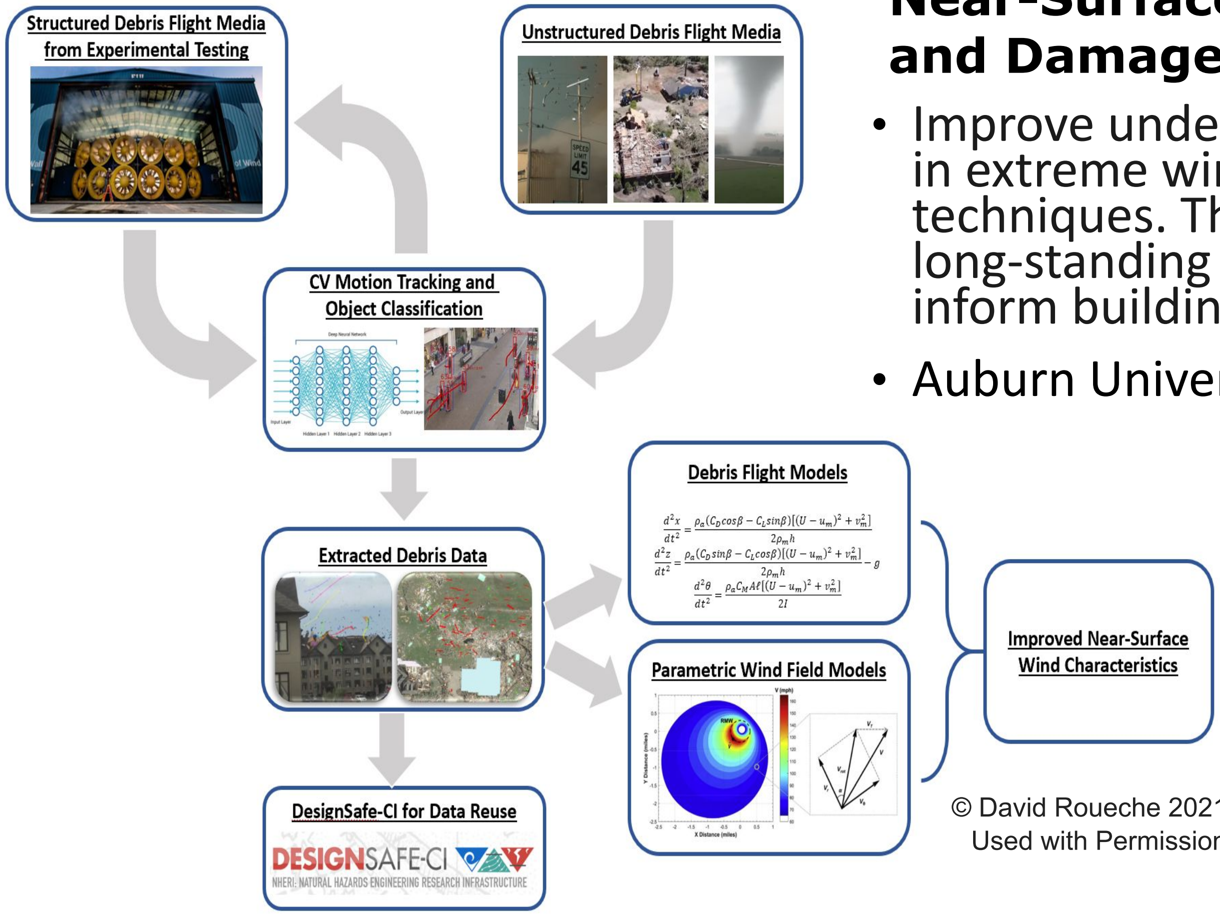
Progress – Tornado Wind Measurements

R1: Development and deployment of technology to measure tornado wind fields

Recently funded award through the joint NIST/NSF Disaster Resilience Research Grants (DRRG) program*



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Reconstruction of Four-Dimensional Near-Surface Wind Characteristics from Debris and Damage Attributes using Computer Vision

- Improve understanding of near-ground-level winds and debris in extreme windstorms using new computer vision techniques. The results of this work could address a long-standing gap in our characterization of windstorms and inform building codes and standards.
- Auburn University & UIUC

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* https://www.commerce.gov/news/blog/2022/05/nist-nsf-award-more-76-million-support-disaster-resilience-research

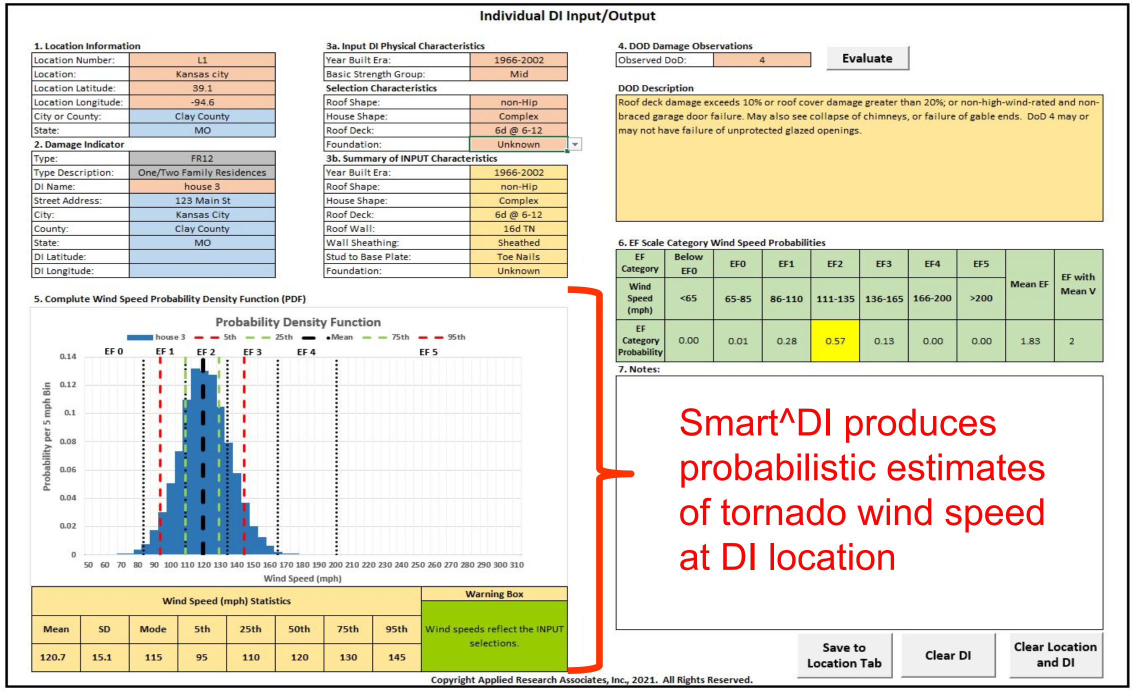
Progress – Improvement of the EF Scale (1/2)

R4: Standardize the Enhanced Fujita (EF) scale and improve through addition of scientific/quantifiable damage indicators, particularly those that distinguish between the most intense tornado events

ASCE/AMS Standard on Wind Speed Estimation in Tornadoes and Other Windstorms

(NOAA and NIST co-chair this standards committee)

- Chapters for all methods in the standard are being balloted
  - Radar
  - In Situ
  - **EF-Scale Method**
  - Forensic Engineering
  - Forrest Damage/Treefall Pattern
  - Remote Sensing Condition Assessment
- Completed beta-testing of 'Smart DI'
  - 20 participants in the pilot study, including ≈ 10 NWS Weather Forecast Offices
  - Results helpful for improvement of the software interface and proposal for incorporation of Smart^DI into WSE Standard



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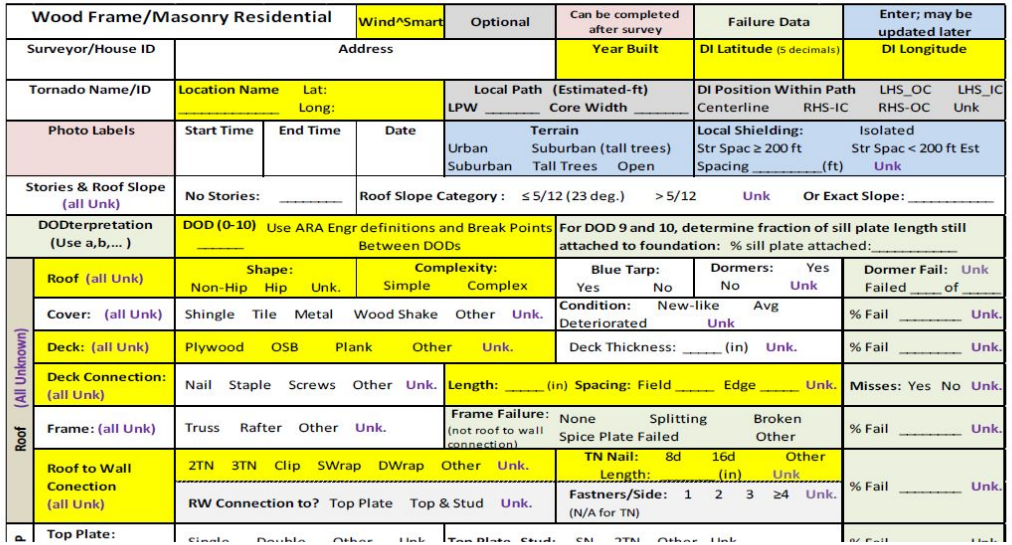
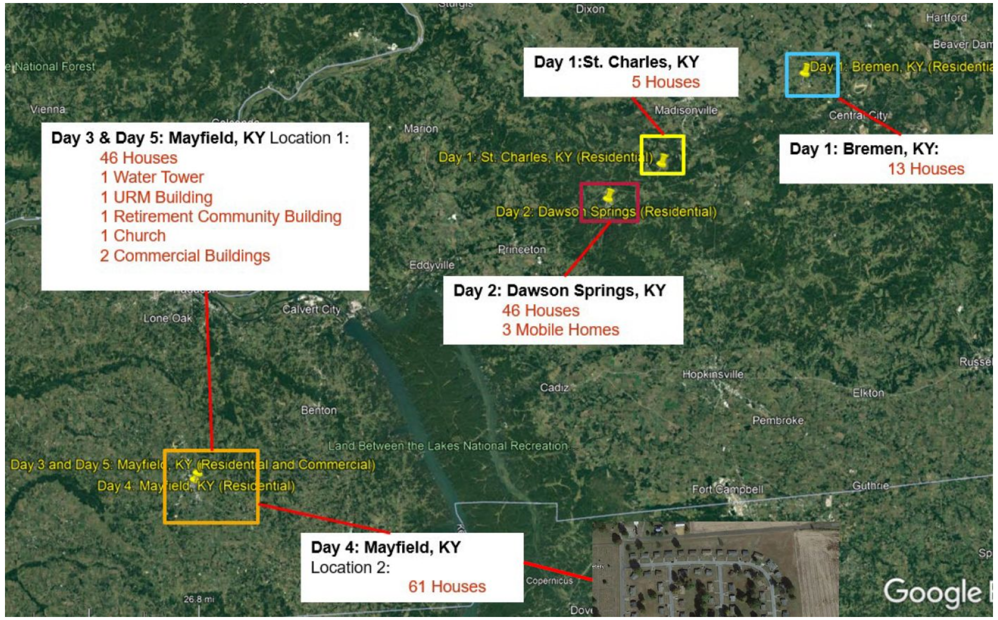
Progress – Improvement of the EF Scale (2/2)

- Conducted field data collection (via contractor) for historic Dec. 10-11, 2021 "Quad-State" Tornado Outbreak
    - Developed highly detailed data collection form, including components needed for finite element modeling
    - Collect detailed field data on tornado damage to residential structures to support additional validation of the Smart^DI method, tool, and proposal to WSE Committee
    - Surveyed 169 homes in several neighborhoods - using 2 approaches
        - Transect across path
        - 100% survey within location polygon
- Held a workshop to promote data sharing and research collaboration among the many field research groups investigating the Quad-State Outbreak (March 7, 2022)



Wood Frame/Masonry Residential	Wind^Smart	Optional	Can be completed after survey	Failure Data	Enter; may be updated later
Surveyor/House ID	Address		Year Built	DI Latitude (5 decimals)	DI Longitude
Tornado Name/ID	Location Name ________ Lat: Long:		Local Path (Estimated-ft) LPW ______ Core Width ______	DI Position Within Path Centerline RHS-IC	LHS_OC LHS_IC RHS-OC Unk
Photo Labels	Start Time	End Time Date	Terrain Urban Suburban (tall trees) Suburban Tall Trees Open	Local Shielding: Str Spac ≥ 200 ft Spacing ________(ft)	Isolated Str Spac < 200 ft Est Unk
Stories & Roof Slope (all Unk)	No Stories: ______	Roof Slope Category : ≤ 5/12 (23 deg.) > 5/12 Unk Or Exact Slope: __________			
DODterpretation (Use a,b,…)	DOD (0-10) ______	Use ARA Engr definitions and Break Points Between DODs	For DOD 9 and 10, determine fraction of sill plate length still attached to foundation: % sill plate attached:__________		
Roof (All Unknown) Roof (all Unk)	Shape: Non-Hip Hip Unk.	Complexity: Simple Complex	Blue Tarp: Yes No	Dormers: Yes No Unk	Dormer Fail: Unk Failed ____ of ____
Cover: (all Unk)	Shingle Tile Metal Wood Shake Other Unk.		Condition: New-like Avg Deteriorated Unk		% Fail ______ Unk.
Deck: (all Unk)	Plywood OSB Plank Other Unk.		Deck Thickness: ____ (in) Unk.		% Fail ______ Unk.
Deck Connection: (all Unk)	Nail Staple Screws Other Unk.	Length: ____ (in) Spacing: Field ____ Edge ____ Unk.			Misses: Yes No Unk.
Frame: (all Unk)	Truss Rafter Other Unk.	Frame Failure: (not roof to wall connection)	None Splitting Broken Spice Plate Failed Other		% Fail ______ Unk.
Roof to Wall Conection (all Unk)	2TN 3TN Clip SWrap DWrap Other Unk.		TN Nail: 8d 16d Other Length: ______(in) Unk		% Fail ______ Unk.
	RW Connection to? Top Plate Top & Stud Unk.		Fastners/Side: 1 2 3 ≥4 Unk. (N/A for TN)		
Top Plate:					



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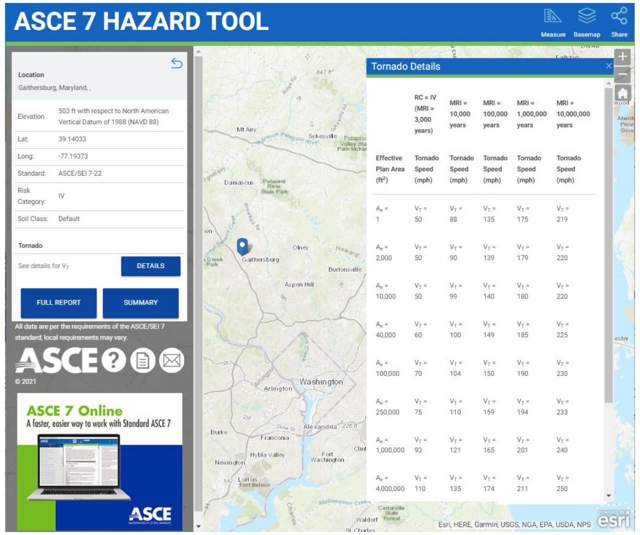
Tornado Load Methodology/Standard

R6: Develop risk–balanced, performance–based tornado design methodologies

R5: Develop PBD standards for tornado-resistant design and adopt in model codes & local regulations

- Led successful resolution of public comments on tornado load provisions in ASCE 7 Chapters 1, 2, 26, 32, Appendix G, and associated commentary
- Includes support for performance-based design (PBD) for tornadoes
  - Tornado PBD explicitly permitted; guidance in commentary
  - Appendix with long return period tornado speed maps
  - Provisions for essential facilities, *intended to remain operational* following extreme environmental loading from tornadoes and other hazards
- Worked extensively with ASCE to confirm tornado speeds in the ASCE 7 Hazards Tool
  - 48 maps in standard + commentary
  - 6 return periods, each w/ 8 effective plan areas
- **ASCE 7-22 and ASCE 7-22 Hazards Tool published Dec. 1, 2022**

Credit: NOAA/OAR/ERL/NSSL



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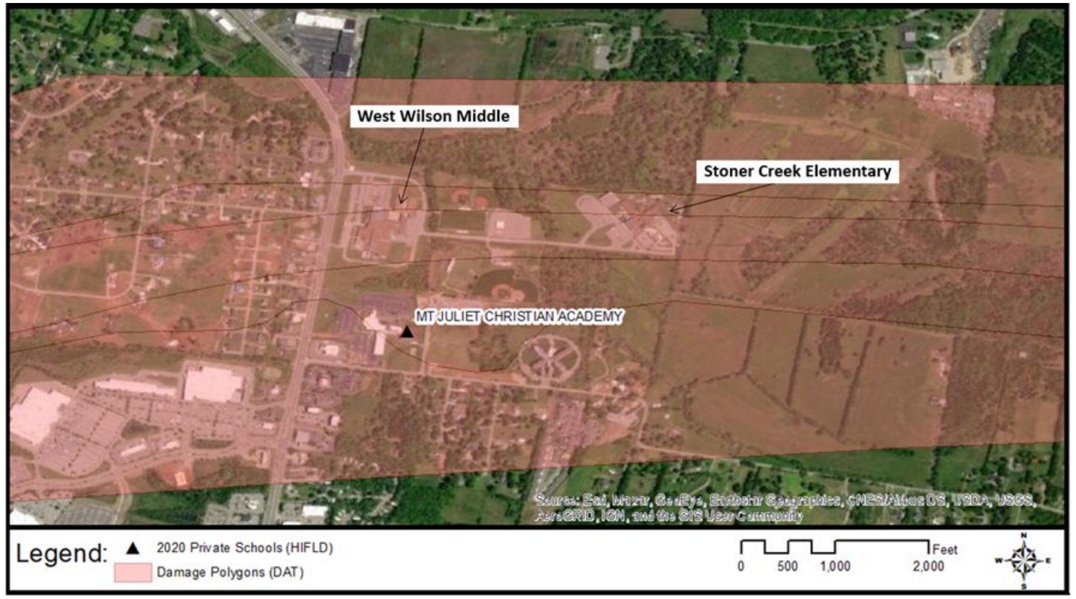
Adoption of Tornado Standard (1/5)

R5: Develop PBD standards for tornado-resistant design and adopt in model codes & local regulations

Multi-part strategy to maximize likelihood of success for incorporation of ACE 7-22 tornado loads into the 2024 IBC

1. Documentation of tornado impacts to critical facilities
2. Economic analysis of ASCE 7-22 tornado load provisions
3. Develop IBC proposal, in collaboration w/ ASCE and FEMA
4. Extensive stakeholder communications



Imagery credits: ESRI, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Damage polygon: NWS.

School Damage - Nashville 2020 Tornado

Credit: NWS

Credit: NWS

Credit: NWS

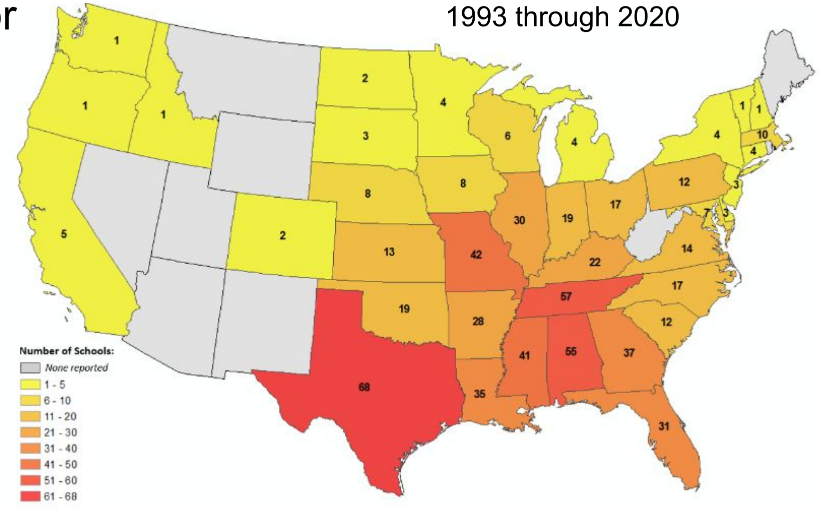
Credit: NWS

Adoption of Tornado Load Standard (2/5)

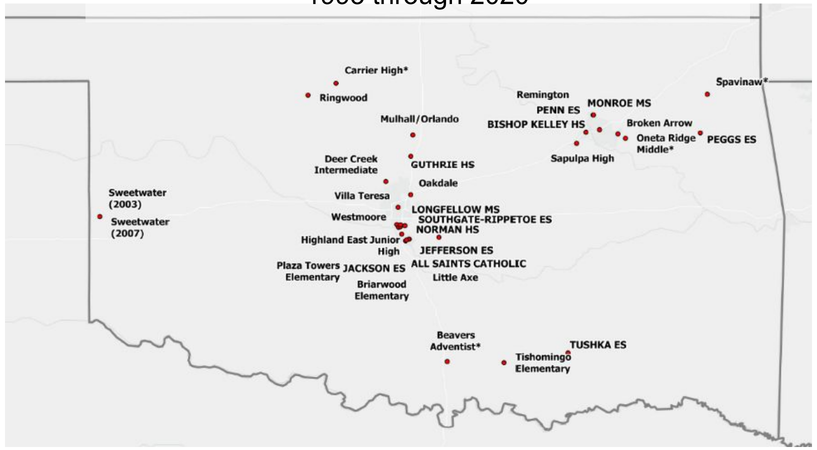
Tornado Impacts to Critical Facilities

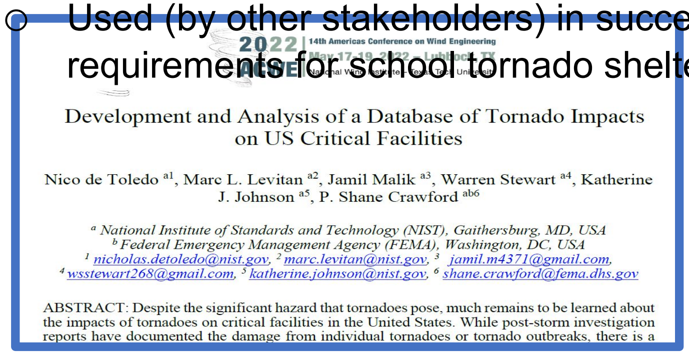
- **Goal:** Help stakeholders make informed decisions on adoption of emerging engineering design standards and codes for tornadoes, and requirements for storm shelters in schools
- **Objective:** Document tornado strikes on critical facilities to better explain cumulative national impacts and local impacts of the >1,250 U.S. tornadoes per year
- **Multiple Methods:**
  1. Mining of NOAA/NCEI Storm Events Database narratives
  2. GIS analysis - intersecting tornado paths w/ critical facility databases
  3. Mining traditional and social media
- **Results:** Initial focus on schools
  - Documented 669 school strikes from 1993-2020 (≈24 per year) using Method 1
  - Prelim results from other methods suggest Method 1 only capturing ≈ 50% of strikes
- **Applications:**
  - Incorporated into IBC Tornado Load Proposal
  - Used (by other stakeholders) in successful defense of Oklahoma Building Code requirements for school tornado shelters

Lower Bound for U.S Schools Struck by Tornadoes, per State
1993 through 2020



Lower Bound - Oklahoma School Strikes
1993 through 2020





2022 | 14th Americas Conference on Wind Engineering
May 17-19, 2022 – Lubbock, TX
ACWE | National Wind Institute – Texas Tech University

Development and Analysis of a Database of Tornado Impacts on US Critical Facilities

Nico de Toledo [a1], Marc L. Levitan [a2], Jamil Malik [a3], Warren Stewart [a4], Katherine J. Johnson [a5], P. Shane Crawford [ab6]

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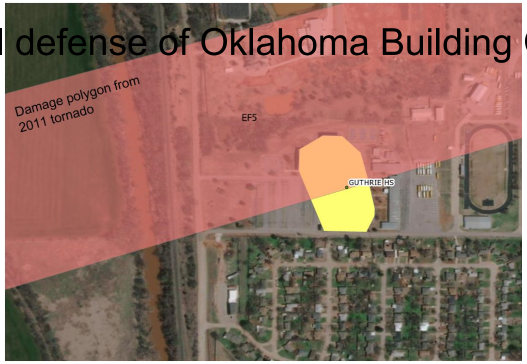
[4] wsstewart268@gmail.com, [5] katherine.johnson@nist.gov, [6] shane.crawford@fema.dhs.gov

ABSTRACT: Despite the significant hazard that tornadoes pose, much remains to be learned about the impacts of tornadoes on critical facilities in the United States. While post-storm investigation reports have documented the damage from individual tornadoes or tornado outbreaks, there is a



Imagery credits: Esri, Maxar, Microsoft, Earthstar Geographics, and the GIS User Community

Adoption of Tornado Load Standard (3/5)

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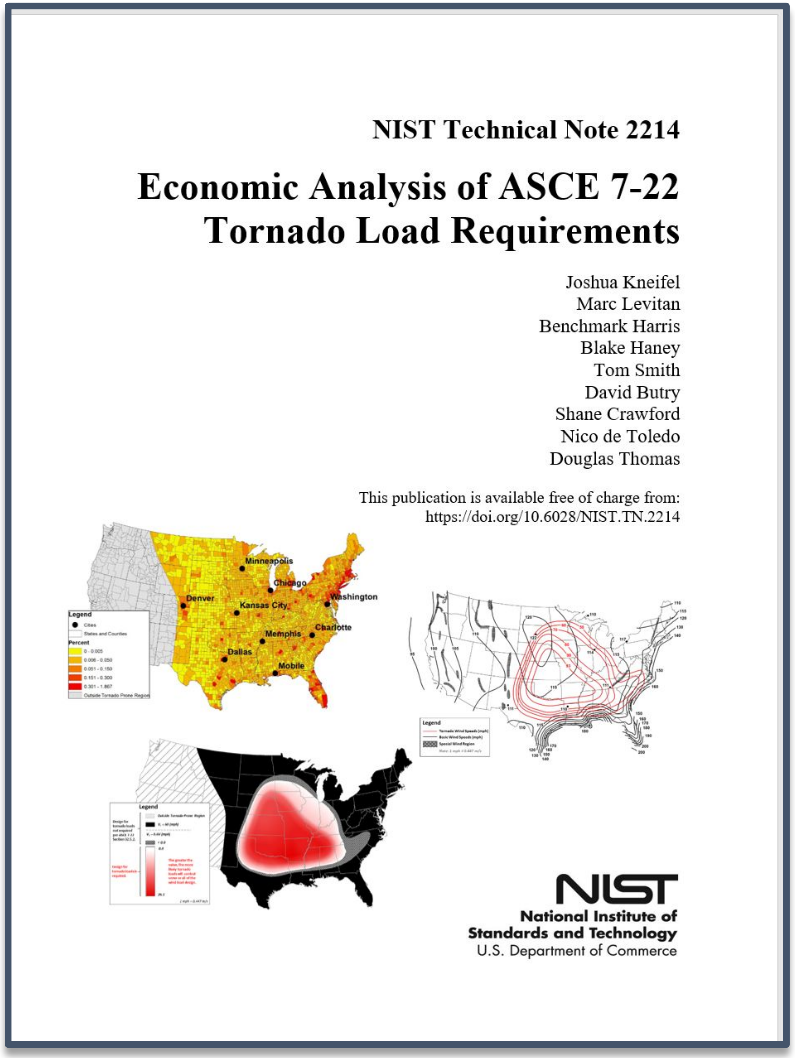
Economic Analysis of ASCE 7-22 Tornado Loads

- **Fraction of new buildings impacted by tornado load requirements**
- **Comparisons of tornado loads vs wind loads**
  - Elementary and high school, fire station, hospital examples
  - Tornado loads can increase wind loads by >100%, particularly in Exposure B and where wind pressures are smallest magnitude – field of the roof, leeward wall
- **Impacts on Roof System Design**
  - Typically modest increases in fasteners, adhesives, pressure ratings
- **Estimated cost increases for tornado loads**
  - Typically <0.15% of total construction costs

Estimated Cost Impacts from Tornado Loads – High School

Cost Item	Charl.	Chicago	Minn.	DFW		Kansas City		Memphis	
	B	B	B	B	C	B	C	B	C
Roof Fasteners	$0	$0	$0	$300	$0	$11 943	$0	$8294	$0
Diaph.	$0	$0	$0	$0	$0	$0	$0	$0	$0
Joists & WF	$0	$165 023	$0	$139 778	$8495	$137 401	$8350	$140 616	$8546
Wall Frame	$0	$0	$0	$90 000	$0	$70 020	$0	$87 480	$0
Found. Anchor.	$2391	$20 835	$12 675	$20 000	$15 574	$16 160	$13 738	$19 140	$19 140
Total	**$2391**	**$185 857**	**$12 675**	**$250 077**	**$24 069**	**$235 525**	**$22 088**	**$255 530**	**$27 686**
Budget ($million)	$200.45	$280.68	$248.64	$200.00	$200.00	$198.64	$198.64	$222.73	$222.73
Pct of Budget	**0.001 %**	**0.07 %**	**0.005 %**	**0.13 %**	**0.01 %**	**0.12 %**	**0.01 %**	**0.11 %**	**0.01 %**

Note: Exposures not displayed had zero cost impacts from tornado loads


NIST Technical Note 2214

Economic Analysis of ASCE 7-22 Tornado Load Requirements

Joshua Kneifel
Marc Levitan
Benchmark Harris
Blake Haney
Tom Smith
David Butry
Shane Crawford
Nico de Toledo
Douglas Thomas

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.2214

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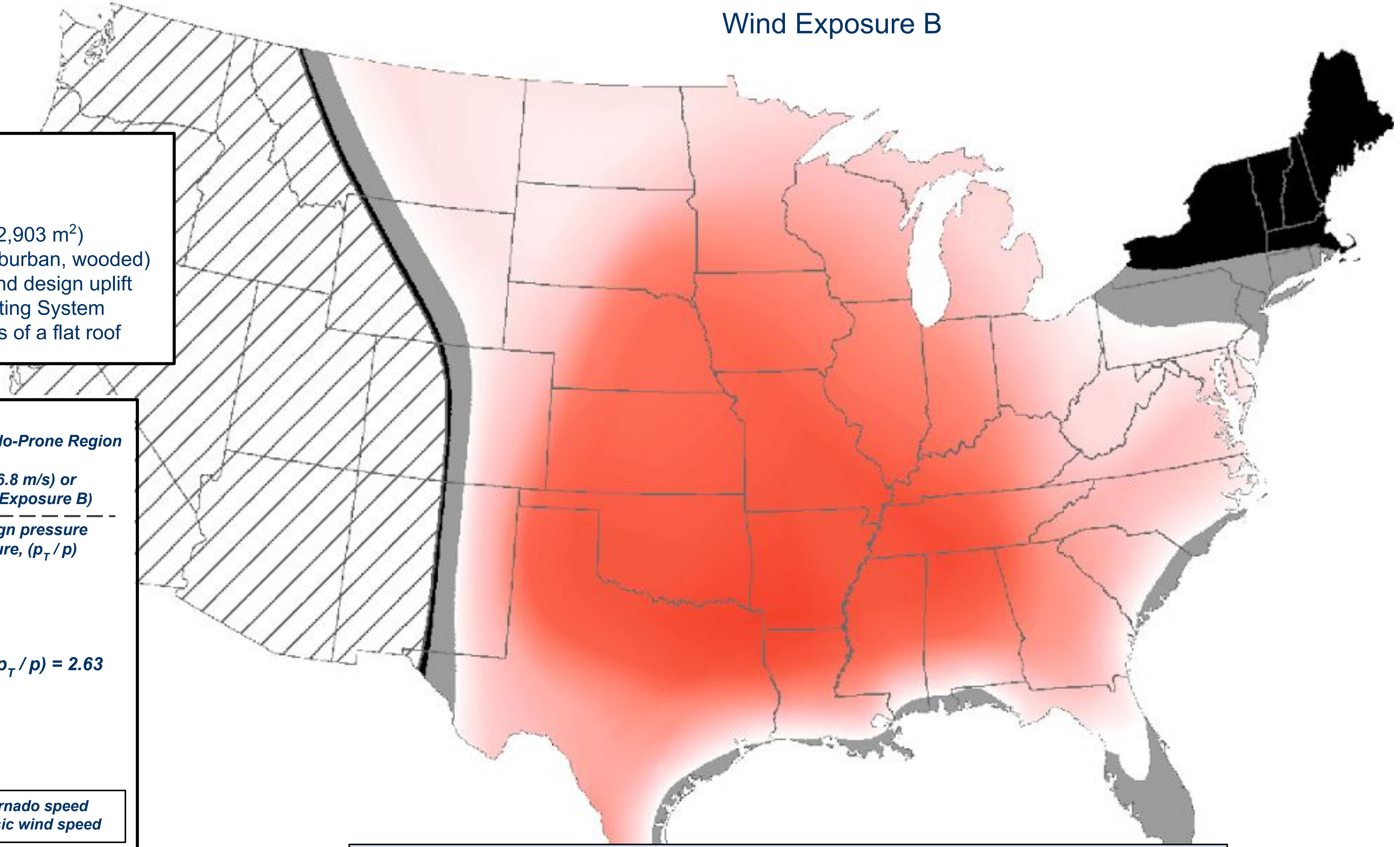
https://doi.org/10.6028/NIST.TN.2214

Where do Tornado Loads Control?
The answer is very building specific.

Hospital Example
MWFRS – Uplift on Leeward Roof
Tornado/Wind Pressure Ratio
Wind Exposure B

Design Parameters

- 5-Story Hospital
- Risk Category IV
- Effective Plan Area = 1,000,000 ft^2 (92,903 m^2)
- Exposure B for wind loads (urban, suburban, wooded)
- Comparing ASCE 7-22 tornado vs wind design uplift pressures for Main Wind Force Resisting System (MWFRS) loads on leeward elements of a flat roof



Legend

Design for tornado loads not required per ASCE 7-22 Section 32.5.2
- *Outside Tornado-Prone Region*
- *V_T < 60 mph (26.8 m/s) or V_T < 0.5V (for Exposure B)*

Design for tornado loads required but does not control

Ratio of Tornado design pressure to Wind design pressure, (p_T / p)
- *< 1.0*

Design for tornado loads is required; Tornado loads control over wind loads
- *1.0*
- *1.5*
- *3.0*

Max (p_T / p) = 2.63

V_T = Tornado speed
V = Basic wind speed

Tornadoes will control MWFRS leeward roof uplift for this specific hospital example over most of the eastern 2/3 of the US.

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Adoption of Tornado Load Standard (4/5)

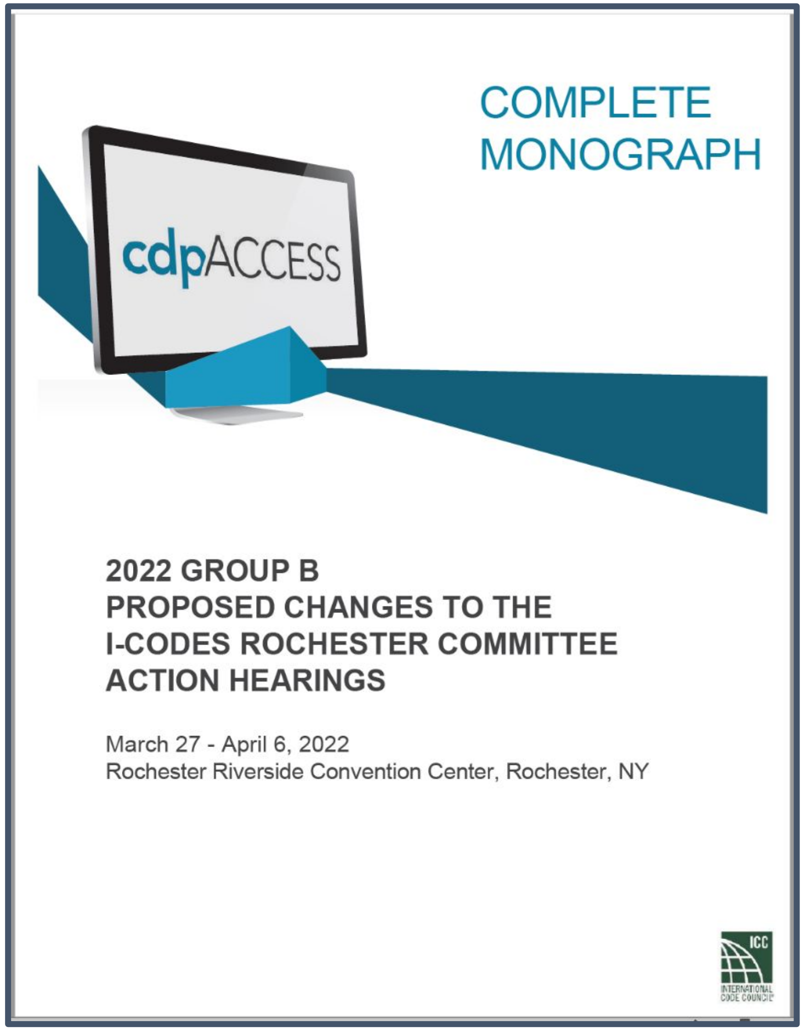
2024 International Building Code

- **NIST led development of the proposal to incorporate ASCE 7-22 Tornado Load requirements into the 2024 IBC**
  - with ASCE and FEMA

- **Coordinated testimony for the Committee Action Hearings**

- **IBC Structural Committee voted 14-0 to approve**

- **Next Steps**
  - Public Comment Hearings
  - Online Government Consensus Vote


COMPLETE MONOGRAPH

cdpACCESS

2022 GROUP B
PROPOSED CHANGES TO THE
I-CODES ROCHESTER COMMITTEE
ACTION HEARINGS

March 27 - April 6, 2022
Rochester Riverside Convention Center, Rochester, NY

Tornado Loads: Proposal S63-22

Adoption of Tornado Load Standard (5/5)

Stakeholder Communications

- **33 presentations/webinars/seminars, including**
  - Structures Congress, 14th Americas Conf on Wind Eng, National Disaster Resilience Conf, ICC Tornado Webinar, …
  - NSTC Science for Disaster Reduction (SDR) Interagency WG
  - FEMA Risk Management Division
  - Recovery Support Function Leadership Group (RSFLG)
  - Mitigation Framework Leadership Group (MitFLG)
  - Federal Energy Regulatory Commission (FERC) (2)
- **17 media interviews**
  - New York Times, Washington Post, St. Louis Post Dispatch
  - Engineering News Record (2), ICC Building Safety Journal, ASCE (2), Construction Forum, Construction Broadsheet (2)
  - NPR, St. Louis Public Radio, Infrastructure Show Podcast
  - Scripps TV, KMOV-CBS St. Louis, KSDK Channel 5 St. Louis
- **Oral and written testimony for Illinois House of Representatives**
  - Labor and Commerce Committee

An official website of the United States government Here's how you know

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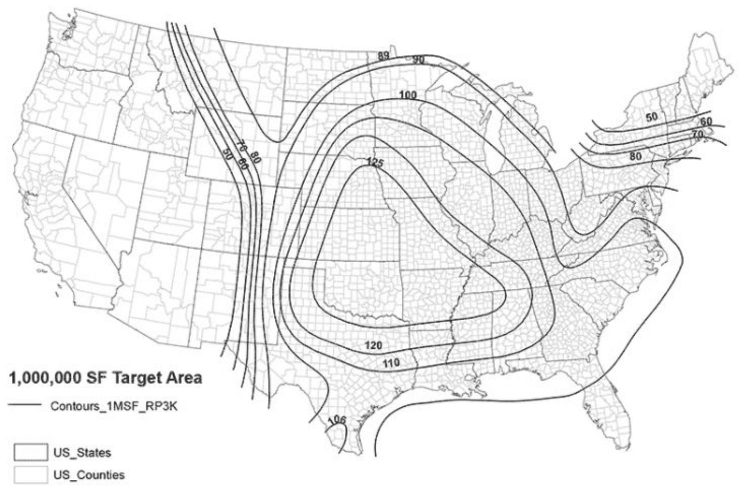
NEWS

Major New Building Standard Can Map Out Tornado Threat for the First Time

June 21, 2021



Of the natural hazards in Mother Nature's arsenal, tornadoes are some of the most vicious. But while other hazards are regularly considered in building designs, tornadoes have not been part of the equation for most structures in the United States, even in highly tornado-prone regions. Now, an upcoming edition of a critical building standard gives tornadoes some much needed attention.

https://www.nist.gov/news-events/news/2021/06/major-new-building-standard-can-map-out-tornado-threat-first-time

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Impacts / Outreach Summary

Published
In progress
In planning / development

- **Existing Standards**
  - **NFPA 1600-2019**, Standard on Continuity, Emergency, and Crisis Management
  - **ICC 500-2020**, Standard for Design and Construction of Storm Shelters
  - **ASCE/SEI 7-22**, Minimum Design Loads and Associated Criteria for Buildings and Structures ← Published December 2021
  - **ICC 500-2023**, Standard for Design and Construction of Storm Shelters ← Initiated in December 2021
- **New Standards**
  - **NFPA 1616-2017**, Standard for Mass Evacuation and Sheltering
  - **ASCE/AMS** Standard for Estimation of Wind Speeds in Tornadoes ← In Main Cmte Ballot
- **Building Codes**
  - **2018 International Building Code (IBC)**
  - **2018 International Existing Building Code (IEBC)**
  - **2024 International Building Code (IBC)** ← In Public Comment
- **Guidelines**
  - **FEMA P-320**, Taking Shelter from the Storm, 4th ed.
  - **FEMA P-320**, Taking Shelter from the Storm, 5th ed.
  - **FEMA P-361**, Safe Rooms for Tornadoes and Hurricanes, 3rd ed.
  - **FEMA P-361**, Safe Rooms for Tornadoes and Hurricanes, 4th ed. ← Published April 2021
  - **ICC 500-2014**, Commentary on the Standard for Design and Construction of Storm Shelters
  - **ICC 500-2020**, Commentary on the Standard for Design and Construction of Storm Shelters ← In press
  - **FEMA P-2062**, Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities
  - **NIST Technical Note,** Alerting under Imminent Threat: Guidance on alerts issued by outdoor siren and short message alerting systems
  - ***Nat. Hazards Rev.***, Alerts and warnings on short messaging channels: guidance from an expert panel process
  - **FEMA P-431**, Tornado Protection: Selecting Refuge Areas in Buildings, 3rd ed.
  - Guidelines for Tornado Resistant Design of Risk Category II Buildings ← Initiated in May 2022
  - Guidelines for Public Tornado Sheltering Strategies

Workshops

- 1st NIST/ASCE Tornado Map Stakeholder Workshop, 2015
- Federal Agency Tornado Map Workshop, 2015
- Workshop on Outdoor Siren Policies, 2016
- Workshop on Short Message Alerting, 2017
- Public Tornado Shelter Workshop: Opportunities and Challenges for Improving Tornado Safety, 2019
- 2nd NIST/ASCE Tornado Map Stakeholder Workshop, 2019
- Quad-State Tornado Outbreak Workshop, 2022 ← Held in March

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Remaining Implementation Tasks

Legend
- Primarily Completed
- Significant Activities/Progress
- Modest Progress
- Next Steps

Category	R#	RECOMMENDATION SUMMARY	Next Steps
Hazard Characteristics	1	Develop and deploy technology to measure tornado wind fields	
	2	Archival of tornado event data	Linked with efforts for R4
	3	Development of tornado hazard maps	Propose for ANS 2.3 Std on Tornado Characterization for Nuclear Facility Sites
	4	Improvement of EF Scale; adoption by NWS	Complete the new ASCE/AMS Standard
Buildings, Shelters, Designated Safe Areas, and Lifelines	5	Develop PBD standards for tornado-resistant design/adopt in codes	Proposed for IBC 2024; Propose ASCE 7-22 Tornado Loads for the ICC 500-2023 Storm Shelter Standard
	6	Develop performance-based tornado design methodologies	Develop guidance for RC II Buildings
	7	a) Develop tornado shelter standard for existing buildings; b) Installation of tornado shelters in more buildings in tornado-prone regions	
	8	Develop guidelines for public tornado sheltering strategies	Develop guidance w/ FEMA and NOAA
	9	Develop guidelines for selection of best available refuge areas	Complete guidance w/ FEMA
	10	Prohibition of aggregate/ballast roof coverings in tornado-prone regions	Revise/Resubmit to IBC
	11	Develop req. for enclosures of egress systems in critical facilities	ASCE 7-22 tornado provisions incl. significantly enhanced requirements for critical facilities
	12	a) Develop tornado vulnerability assessment guidelines for critical facilities; b) Performance of vulnerability assessments by critical facilities	Coordinating w/ FEMA
Emergency Communication	13	Develop codes, standards, and guidance for emergency communications; Develop joint plan by emergency mgrs/media/NWS for consistent alerts	
	14	Deploy "push" technologies for transmission of emergency information	
	15	Research to identify factors to enhance public perception of personal risk	
	16	Develop technology for real-time, spatially-resolved tornado threat information	NOAA

Progress on Implementation of Past Investigation Recommendations

June 8-9, 2022
NCST Advisory
Committee Meeting

NOTE – Summaries of the recommendations are included in the following slides for context. The complete recommendations are available in the final report of the NIST Technical Investigation of the Joplin Tornado, at https://dx.doi.org/10.6028/NIST.NCSTAR.3

QUESTIONS?

Please 'raise your hand' using the Blue Jeans Participant window and unmute your audio and video

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